The DAO's Stratospheric Research

Since the early 1990s, the DAO has incorporated the middle atmosphere in its data assimilation system. This was initially in support of NASA's Upper Atmosphere Research Satellite (UARS), which provided space-based measurements of a number of important stratospheric trace gases. The DAO's assimilated datasets provide meteorological fields in the middle atmosphere, which have been extensively utilized for studies of meteorology and trace-species transport.

As the baseline assimilation system used in the DAO has evolved, so have the characteristics and quality of the middle atmospheric products. Increases in both horizontal and vertical resolution have proven beneficial to the system; the peak vertical resolution (70 levels in the model) was reached with the GEOS-2 analysis system, after which it was decreased (to 48 levels) in GEOS-3 in order to facilitate an increase in horizontal resolution (from 2.5º [longitude] × 2º [latitude] to 1º × 1º). Most of the reduction in vertical resolution was accommodated above the middle stratosphere and there was little impact in this change from 70 to 48 levels. One characteristic of the analyses in the middle atmosphere has been the noisy nature of the fields, which is particularly pronounced in baseline fields (such as temperature) in the upper stratosphere, but is evident in derived dynamical quantities (such as vertical velocities and potential vorticity) at much lower levels.

The prototype GEOS-4 assimilation system shows much reduced noise levels and generally produces a more accurate geophysical product. These improvements are largely due to the new atmospheric general circulation model that lies at the core of GEOS-4; the most important advance is that the sigma-coordinate framework used in GEOS-1, 2 and 3 has been replaced by hybrid coordinates, with a transition from sigma to pressure as altitude increases, but other major factors include the use of a Lagrangian vertical coordinate in the adiabatic calculations and the flux-form semi-Lagrangian form of the horizontal components of the Navier-Stokes Equations. These factors lead to substantial improvements in the DAO's products.

A major application of middle atmospheric analyses is to drive chemical-transport models, which use the meteorological variables (wind and temperature) to transport many trace species and to calculate the temperature dependent kinetic reactions and photolysis rates. Using the various versions of the analyses, DAO scientists have collaborated with other NASA groups and external users in performing research that has led to deeper understanding of the ozone distribution. Transport studies using idealized tracers as well as realistic trace species, including ozone, are among the most demanding of applications for assimilated datasets. The improved physical nature of the GEOS-4 products are most revealing in this context; important features of the middle atmosphere, such as the quasi-isolation of tropical and extratropical air masses are represented much more realistically in GEOS-4 than in any previous product.

DAO scientists work closely with the atmospheric chemistry community. There are presently three important foci in the DAO's support of the middle atmospheric community.

The first is the operational product, which is used extensively to support NASA and other aircraft and space-based missions. (This support of middle atmospheric campaigns has also now extended to tropospheric missions, such as Trace-P.) The DAO supported the extensive SOLVE mission in Kiruna in the northern winter of 1999/2000 and will similarly support SOLVE-2 in the early part of

2003. A DAO team will also participate in NASA's CRYSTAL-FACE mission, aiming to understand cirrus clouds and water vapor in the upper troposphere/lower stratosphere, in July 2002.

The second is the preparation for the lauch of EOS-Aura in late 2003, where observations of numerous trace species will once more be made; this mission will extend the observational quality of the prior UARS mission, using newer technology to observe more in the region surrounding the tropopause, a region of great scientific interest. For this mission, the DAO will make use of meteorological analyses, as well as expanding its activities in ozone assimilation to fully exploit the multiple instruments observing ozone and other trace species.

The third major activity is reanalysis, focusing initially on the period beginning in 1991 (prior to the eruption of Mt. Pinatubo and the launch of UARS). The project Reanalysis for Stratospheric Trace gas Studies (ReSTS) will focus initially on the period May 1991- April 1995, producing assimilated datasets using a baseline assimilation system and several modified versions. These experiments will allow investigation of the sensitivity of the assimilation system to several factors, most especially the atmospheric model (mainly the representation of sub-grid-scale gravity-wave drag and the radiative feedbacks of volcanic aerosols and ozone) and the data used: a major component will assimilate the limb-sounding data available from the UARS satellite, which will complement the TOVS dataset which are used in the baseline products. The reanalysis will eventually extend to from 1991 to the present, using a constant system, and plans are underway to perform a more ambitious multi-decadal reanalysis, beginning in 1979 (when space-based observations became available on a routine basis).

The DAO's middle atmospheric research proceeds alongside the tropospheric work; the two aspects are not independent, since a good middle atmospheric product depends on having an accurate troposphere, and also an realistic depiction of the middle atmosphere helps in producing an accurate tropospheric analysis. Many aspects of the applications are coming closer together, especially in relation to trace-species modeling and assimilation, with more space-based observations of troposphere gases such as CO. Stratospheric research in the DAO utilizes a highly coupled system, focusing on problems specific to the middle atmosphere, but interacting closely with the meteorological research throughout the DAO.